Railroad ; Mr. Henry Keep and Mr. M. L. Sykes, of the Chicago and Northwestern Railroad ; Mr. Sidney Dillon and Mr. Jay Gould, of the Union Pacific Railroad ; Mr. William H. Fargo, of the American Express Company ; Mr. Frederic Lovejoy, of Adams' Express Company, and the Superintendent of the Union Pacific Express Company. The cordial appreciation by these gentlemen of the fact that the work in which we were engaged was one of a purely scientific character, and as such was one to which every reasonable facility should be furnished, was as gratifying to us as it was honorable to them. I should fail to do exact justice were I to omit mention of the service rendered us by Mr. J. J. Dickey, the Superintendent of the Union Pacific Telegraph ; Mr. E. Dickenson, Superintendent of the Laramie Division; Mr. R. M. Galbraith, Superintendent of the Repair Shops at Rawlins ; Major Thornburgh, Commanding Officer at Fort Fred Steele, with Capt. Bisbee and Surgeon De Witt, his associates in the service ; Mr. Lawrence Hayes, of the Railroad Hotel, and to Mr. J. B. Silvis, of the photographic car. "Of the citizens of Rawlins," says Dr. Draper, "it is only necessary to say that we never even put the lock on the door of the observatory, and not a thing was disturbed or misplaced during our ten days of residence, though we had many visitors."

The agreeable party, the pleasant surroundings, the charming weather, the kindness of friends, and above all, the capital success of the observations, make the Draper Eclipse Expedition an exceedingly pleasant memory to us all.

Notes on a series of Analyses of the Dolomitic Limestone Rocks of Cumberland County, Pa., made by Messrs. Hartshorne and Hartranft in the Laboratory of the Second Geological Survey of Pennsylvania. By J. P. Lesley, State Geologist.

(*Read before the American Philosophical Society, October* 18*th*, 1878.)

At a meeting of the American Philosophical Society, Dec. 20, 1877, I described the progress of an elaborate investigation which I had instituted for the purpose of determining whether or not any fixed or rational order of deposition could be observed in our Lower Silurian, or Siluro-Cambrian Magnesian Formation (No. II).

I selected a fine exposure made by the rock cut of the Northern Central Railroad, on the west bank of the Susquehanna river, opposite Harrisburg, where a consecutive series of the beds, all conformable and all dipping regularly about 30° to the southward, afforded a good opportunity for collecting two sets of specimens for analysis, one at the bottom and the other at the top of the cut ; and great care was taken to survey the cut, mark the beds (from 1 to 115) and range the specimens in two parallel series ; so that any lack of homogeneousness in any bed might be detected by analyses of two specimens taken from places in the edge of the bed from 5 to 30 feet apart, according to the depth of the cut, and sometimes by the selection of a third and intermediate specimen, many of the analyses of individual specimens being also repeated.

The investigation was continued throughout the winter by Mr. Henry Hartshorne, and completed during the summer by Mr. Hartranft; and I now find myself able to bring some of the results to the notice of the Society in the form of tables, (1) of analyses, and (2) of averages. At a future time I will be able to carry the discussion of averages still further, and can then venture to base upon them some hypothetical conclusions of great interest to geologists who occupy themselves with the problem of the genesis of our limestone deposits.

Table I, gives the whole series of analyses made; but includes only the determinations of Carbonate of Lime, Carbonate of Magnesia, and Insoluble Matter; omitting the determinations of oxide of iron, alumina, sulphur, phosphorus and carbon.

This table shows to the eye, without need of a diagram, the remarkable alternations of limestone beds with dolomitoid beds throughout the series.

TABLE I.

Analyses of specimens taken from railroad cuttings opposite Harrisburg; in two series: one at railroad grade; the other near the top of the cut.

NOTE, when the analysis was repeated, with slight difference, the average is given; but the instances of this are few.

Bed.	Lime Carb.		Magnesia Carb.		Insol. Matter.	
	Grade.	Top.	Grade.	Top.	Grade.	Top.
1	58.35	57.10	36.80	38.25	4.60	4.00
2	55.60	56.20	38.50	39.75	5.30	3.80
(*a*) 3*a*	89.90	92.00	3.60	4.00	5.70	4.10
4	93.90	97.05	1.80	1.85	3.80	1.40
(*b*) 5	96.40	97.20	1.40	0.70	1.90	2.10
6	95.50	97.60	1.40	1.30	1.50	1.10
7	87.10	87.40	3.60	3.70	9.70	9.10
(*c*) 8	82.30	87.45	14.50	7.50	3.10	3.90
(*e*) (*d*) 9	68.30	67.60	24.80	27.00	5.50	5.40
10	90.70	90.40	8.05	8.15	1.90	1.70
11	97.60	96.70	1.80	1.30	1.00	2.20
12	66.00	75.80	32.40	19.85	1.60	2 50
13	96.80	97.20	2.30	1.85	1.20	1.40
14	95.85	83.70	2.40	11.85	1.80	3.40
15	92.75	97.30	4.45	1.00	3.40	1.80
(*a*) (3*b*)	(67.20)	(66 50)	(3.20)	(4.10)	(26.60)	(25.30)
(*b*) (flint in 5)	6.50	9.30	0.80	0.30	90.80	89.90
(*c*) Dup. (1)	72.15		21.70		6.30	
(*d*) Intermed. (9)	63.60		30.85		5.10	
(*e*) Calcite (9)	88.70	88.60	0.80	0.90	10.40	9.90

16	97.80	97.10	1.30	2.00	1.10	1.20
(*f*) 17	97.60	[60.20]	1.10	[33.40]	1.10	[5.90]
18	97.00	93.50	1.20	4.30	1.40	2.00
19	65.30	62.30	30.80	34.50	3.50	3.00
20	96.40	98.70	2.90	0.80	0.70	0.50
21	76 30	71.75	18.50	24.30	5.30	4.20
22	93.7	97.4	3.8	1.6	1.9	1.3
(*g*) 23	65.3	64.3	30.8	28.6	3.4	6.5
24	94.8	93.1	1.6	1.9	3.9	4.8
25	68.9	68.9	23.8	23.6	7.4	6.3
(*h*) 26	90.0	[70.85]	6.8	6.3	3.4	[22.95]
(*i*) 27	63.3	75.7	28.60	18.1	6.2	5.6
(*j*) 28	81.25	94.15	6.65	2.15	12.0	4.0
29	65.0	62.4	29.1	31.4	5.4	5.4
30	98.9	97.9	1.1	1.30	0.5	0.9
31	61.0	64.30	27.7	25.20	10.9	10.3
32	96.7	97.6	1.7	1.0	1.7	1.8
33	73.3	71.9	12.4	15.5	12.4	10.4
34	97.6	96.3	1.5	1.2	1.1	1.5
35	75.20	67.25	18.90	25.65	4.7	5.9
36	82.9	79.9	13.5	16.9	2.7	4.2
37	91.0	89.0	5.4	5.8	3.6	3 6
38	79.7	82.9	16.9	12.3	2.9	2.8
39	89.7	98.7	8.2	1.6	1.6	0.3
40	61.5	56.3	33.6	37.2	4.7	6.1
41	96.9	95.8	1.7	2.2	1.4	1.9
42	55.6	57.15	35.0	34.95	6.9	6.5
(*k*) 43	97.8	[91.0]	1.3	[1.3]	1.3	[7.9]
(*l*) 44	73.6	65.5	22.5	28.2	3.4	4.8
(*m*) 45	96.2	[96.2]	2.0	[2.0]	2.4	[2.4]
46	97.2	90.6	1.7	7.6	0.7	1.8
47	63.4	68.2	29.5	27.1	6.4	3.6
48	94.3	95.3	1.9	2.2	3.5	2.2
(*n*) 49	57.8	66.2	33.2	26.9	8.0	5.7
50	60.4	62.0	32.1	31.7	5.3	5.1
51	92.9	95.7	3.2	2.9	3.0	1.7
52	61.4	68.9	31.9	23.7	5.3	7.2
53	81.1	88.7	10.0	7.0	4.7	3.4
54	98.2	97.9	1.3	1.2	1.2	0.7
55	79.8	79.5	10.8	13.4	8.6	6.9

(*f*) Upper specimen evidently abnormal; or bed non-homogeneous.

(*g*) Calcite 87.7 1.8 10.4

(*h*) Abnormal (flinty ? in the upper part ?).

(*i*) Abnormal (magnesian in the upper part.)

(*j*) Abnormal (magnesian in the upper part).

(*k*) Abnormal (flinty in the upper part).

(*l*) Upper part more magnesian. This balances 49.

(*m*) It is needful in the averages to *suppose* these brackets. But they are absent from the record.

(*n*) Upper part less magnesian. This balances 44.

	56	66.9	66.0	24.2	23.2	7.4	9.7
	57	91.6	91.0	2.4	2.3	5.9	6.8
	58	64.8	60.1	27.4	29.9	7.2	8.6
	59	97.1	99.3	1.8	1.3	1.1	0.2
	60	75.1	76.3	20.9	19.9	3.1	2.4
	61	89.3	95.1	1.5	1.8	8.9	2.1
(o)	62	[49.8]	61.9	31.9	28.4	[16.9]	8.2
	63	71.0	72.9	23.8	23.0	6.0	4.9
	64	80.7	87.7	14.2	10.0	2.5	2.3
	65	67.7	70.0	20.9	21.5	10.2	7.8
	66	75.1	79.1	19.2	13.6	5.4	5.8
	67	61.0	61.8	33.6	32.1	4.6	5.9
(p)	68	85.1	96.0	[10.4]	2.3	3.2	1.9
	69	51.7	58.5	32.7	27.4	12.9	11.9
	70	98.2	97.4	1.5	1.4	0.8	0.9
	71	55.6	53.3	33.7	35.4	10.3	10.0
	72	98.1	97.3	1.4	1.6	0.8	1.2
	73	93.9	96.6	3.6	1.6	2.7	2.5
	74	95.6	96.8	1.5	1.2	2.8	2.1
	75	91.3	92.1	2.8	3.2	5.4	5.1
	76	64.9	63.0	23.6	26.7	10.6	9.8
(q)	77	85.5	97.9	[9.8]	1.8	4.5	1.0
	78	56.7	56.0	31.9	31.5	8.5	10.8
	79	86.7	85.2	7.1	8.7	5.0	5.5
(r)	80	79.8	95.9	(9.9)	2.0	9.4	2.6
(s)	81	54.9	56.7	[35.7]	24.0	7.7	18.4
	82	84.7	86.9	10.8	8.5	4.1	4.0
	83	90.7	91.0	8.0	7.6	1.7	1.9
(t)	84	66.8	75.6	[27.2]	16.3	4.4	5.6
	85	97.0	93.7	0.9	4.1	8.6	2.1
	86	95.4	98.9	1.3	1.1	3.8	0.6
	87	52.0	54.1	33.7	28.1	12.5	15.9
	88	96.3	98.4	1.9	1.1	2.2	0.7
	89	59.4	61.6	33.7	31.8	6.1	5.9
	90	97.6	97.6	1.8	1.5	0.9	0.3
	91	68.2	74.1	27.9	23.1	3.9	3.0
	92	98 2	97.7	1.3	1.9	1.2	0.6
	93	58.6	59.2	34.1	35.1	5.6	5.0
(u)	94	96.7	85.5	1.4	1.4	1.8	12.6
	95	54.8	55.2	31.1	30.6	13.0	12.9
	96	95.8	95.4	2.7	2.2	1.3	1.8
	97	75.2	77.6	17.3	16.4	6.7	4.8
	98	62.0	60.0	29.4	32.8	7.8	6.7
	99	96.3	96.0	1.9	3.2	1.1	0.9
	100	62.2	62.5	29.5	27.4	8.3	7.1

(o) Abnormal amount of flint in lower specimen.
(p, (q), (r) Local, extra quantity of magnesia in lower specimen.
(s), (t) Excessive amount of magnesia in lower specimen.
(u) Abnormal amount of flint in upper specimen.

101	98.2	98.8	1.2	0.8	0.6	0.3
102	64.4	60 4	30.5	34.2	4.3	4.8
103	94.7	93.1	4.6	4.8	1.0	1.4
104	80.2	79.5	13.2	14.7	5.6	4.3
105	98.2	96.9	1.2	1.6	0.6	1.1
106	63.4	63.3	31.6	31.7	3.8	4.1
107	98.2	99.0	1.6	0.5	0.3	0.4
108	65.0	65.0	29.1	29.6	5.1	5.0
109	94.8	86.9	2.5	4.3	1.8	7.7
110	73.1	64.3	16.5	22.3	9.1	11.6
111	94.5	88.4	2.7	8.3	1.9	2.6
112	54.4	54.4	35.2	36.2	8.4	7.7
113	98.1	76.2	0.9	3.7	1.0	18.2
114	64.6	55.4	26.2	33.8	8.5	9.7
115	95.1	97.7	1.9	0.9	1.7	1.4

Without discussing in detail, at present, this instructive table, several things are evident at a glance, viz: that

1. Alternate strata of limestone and dolomite make up the mass.

2. The dolomite layers carry the most insoluble materials, as a rule.

3. Specimens taken from the top and bottom of the cut (thirty feet apart, or less) differ *sometimes* as notably from one another as specimens taken from different beds but, *as a rule,* each layer is nearly homogenous, so far as two or three analyses can show such a rule.

4. Not one of the so-called dolomite layers has enough carbonate of magnesia to make it a true lithological dolomite. They are all merely more or less magnesian limestones.

5. Carbonate of magnesia is not absent from any bed in the whole series; but in an extensive range (such as from No. 84 to No. 115), out of thirty-two beds *twelve* show less than two per cent., *three* show less than three per cent., and *one* goes up to four and six-tenths per cent. The remaining sixteen beds, alternating with other sixteen with great regularity, carry from thirty-six to fourteen per cent., *nine* of them ranging between thirty six and thirty, *five* between thirty and twenty-five, *one* sinking to seventeen, and *one* to fourteen per cent.

The alternation in these thirty-two beds may be represented to the eye thus:

Per cent. of Carb. Mag.	Nos. of Beds selected from the Series.														
35 and over.															
30 "	...	......	87	...	89	...	91	...	93	...	95	...	...	98	
25 "	84														
20 "															
15 "	...	......	...	...	...	...	...	...	...	...	...	...	97		
10 "															
5 "															
0 "	...	85, 86	...	88	...	90	...	92	...	94	...	96	...	...	99

Per cent. of Carb. Mag.	Nos. of Beds selected from the Series.															
35 and over.													112			
30 “	100		102				106		108						114	
25 “																
20 “																
15 “											110					
10 “					104											
5 “				103												
0 “		101				105		107		109		111		113		115

It is especially remarkable that so few of the beds occupy an intermediate position, chemically considered, between nearly fixed extreme limits of lime and magnesia.

Table 2.

In this table the beds are grouped by fives, and averaged.

	Lime Carbonate.		Magnesia Carb.		Insol. matter.	
	Bottom.	Top.	Bottom.	Top.	Bottom.	Top.
Beds 1 to 5	394.15	399.50	82.10	84.55	21.30	15.40
“ 6 “ 10	423.90	430.45	52.35	47.65	21.70	21.20
“ 11 “ 15	448.40	450.70	43.35	35.85	9.00	11.30
“ 16 “ 20	454.10	411.80	37.30	75.10	7.80	12.60
“ 21 “ 25	399.00	395.45	78.50	80.10	21.90	23.10
“ 26 “ 30	398.45	401.00	72.25	59.25	27.50	38.94
“ 31 “ 35	403.80	397.35	62.20	68.55	30.80	29.90
“ 36 “ 40	404.80	406.80	77.60	73.85	15.50	17.00
“ 41 “ 45	430.10	405.65	62.50	69.95	15.40	23.50
“ 46 “ 50	373.10	382.30	98.40	95.50	23.90	18.40
“ 1 “ 50	4129.80	4081.00	666.55	690.35	194.80	211.25
Average.......	82.59%	81.62%	13.33%	13.81%	3.99%	4.22%
“ 51 to 55	413.4	430.7	57.2	48.2	22.8	19.9
“ 60	395.5	392.7	76.7	76.6	24.7	27.7
“ 65	357.5	387.4	91.3	84.7	44.5	25.3
“ 70	371.1	392.8	97.4	76.8	26.9	26.4
“ 75	434.5	436.1	43.0	43.0	22.0	20.9
“ 80	373.6	398.0	82.3	70 7	38.0	29.7
“ 85	394.1	403.9	82.6	60.5	26.5	32.0
“ 90	400.7	410.6	72.4	73.5	25.5	23.4
“ 95	376.5	371.7	95.8	92.1	25.5	34.1
“ 96 — 100	391.5	391.4	80.8	82.0	25.2	21.3
“ 51 — 100	3908.4	4015.3	779.5	708.1	283.6	260.7
Average.......	78.17%	80.31%	15.59%	14.16%	5.67%	5.21%
“ 101 — 105	435.7	428.7	50.7	56.1	12.1	11.9
“ 106 — 110	394.5	378.5	81.3	87.4	20.1	28.8
“ 111 — 115	406.7	372.1	66.9	82.9	21.5	39.6
“ 101 — 115	1236.9	1179.3	198.9	226.4	53.7	80.3
Average.......	80.46%	78.62%	13.26%	15.09%	3.58%	5.35%

Beds 1 — 50	4129.80	4081.00	666.55	690.35	194.80	211.25
" 51 — 100	3908.40	4015.30	779.50	708.10	283.60	260.70
" 100 — 115	1236.90	1179.30	198.90	226.40	53.70	80.30
" 1 — 115	9275.10	9275.60	1644.95	1624.85	532.10	552.25
Grand average of 115 beds...	80.655 %	80.668 %	14.30 %	14.13 %	4.627 %	4.802 %

To show how worthless *small groups* are for analytical purposes it is only necessary to *combine* the *top and bottom* specimens of *ten beds*, and notice the absence of any marked regularity, thus:

TABLE 3.

Beds 1 to 10......	L. C. 82.40	M. C. 13.33	I. M. 3.98
Beds 11 to 20......	83.25	9.57	2.03
Beds 21 to 30......	79.69	14.50	5.57
Beds 31 to 40......	80.63	14.11	4.66
Beds 41 to 50......	79.55	16.32	4.06

but, on the other hand when grand averages of fifty beds are taken, a picture is obtained of the pretty uniform distribution of the two carbonates throughout at least this part of the formation, thus:

TABLE 4.

Average of 100 *specimens* (taken from top *and* bottom*) of fifty beds.

Beds 1 to 50....	82.15	13.57	4.11
Beds 51 to 100....	79.54	14.87	5.44
Beds 101 to 115....	79.54	14.17	4.47
Beds 1 to 115....	80.662	14.215	4.715

I shall now give a specimen of the results to be obtained by grouping the *low* magnesian beds together and the *high* magnesian beds together and for the present leave the discussion of the data presented above to others.

I select 14 limestone (A) beds alternating, with singular regularity, with 15 magnesian beds (B, distinguished by black-letter) viz.: beds **87**, 88, **89**, 90, **91**, 92, **93**, 94, **95**, 96, **97**, **98**, 99, **100**, 101, **102**, 103, 104, 105, **106**, 107, **108**, 109, **110**, 111, **112**, 113, **114**, 115; and the result is as follows:

TABLE 5.

	Lime Carbonate.		Magnesian Carb.		Insol. Matter.	
	*Bottom.**	*Top.**	*Bottom.*	*Top.*	*Bottom.*	*Top.*
(A)	96.62	93.47	1.97	2.58	1.24	3.57
(B)	63.83	63.00	27.93	28.52	7.25	7.24

Of the 164 percentages here represented, five are abnormal, as may be noticed by consulting the last part of Table 1. These are included, however, in Table 5. If we combine all the bottom and top analyses of Table 5, without excepting any, we get the following general average:—

* Not of the bed, but of the R.R. cutting.

Table 6.	Lime Carb.	Magnesia Carb.	Insol. Matter.
(A)	95.05	2.27	2.40
(B)	63.41	28.22	7.24

but if we throw out the 5 abnormal analyses, we get the slightly different general average :—

Table 7.	Lime Carb.	Magnesia Carb.	Insol. Matter.
(A)	95.77	2.06	1.42
(B)	63.41	28.22	7.24

and this must be taken as the best expression of the chemical distinction between the purer and the more magnesian limestone layers of our Siluro-Cambrian (Calciferous-Sandstone) Formation, No. II, which we can make at present.

It shows plainly enough that the magnesian limestones are very far from being typical dolomites.

It shows also that the presence of magnesia at the expense of lime is connected *normally* with a high percentage of alumina silicate.

This, it seems to me, goes one step towards settling the *mechanical* theory of the origin of the magnesian carbonate on a sound basis. Although we may have to seek long for the source of the sediment, as a whole it must have a source which is common also to the clay.

Difficulties multiply upon us in studying such data. No satisfactory explanation of the bedplate structure of the mass has yet been offered. If the deposit be in the main mechanical and not chemical, it is strange that such sharp distinctions between layer and layer should have been made in the bed of a deep ocean. It is still more strange, that (on this hypothesis) strongly marked local abnormal analyses should be encountered.

This leads me to say that the above investigation is imperfect because carried on in a vertical plane only. It should now be repeated in a horizontal plane. It is desirable to learn whether the *geographical* changes may not be great enough to convert a limestone bed here into a dolomitoid there, half a mile (or perhaps 100 yards) distant. If this prove true (and the possibility of it is indicated by the abnormal analyses), then a new difficulty arises in the way of a sound theory of the origin of the bed plates ; and confuses still more any mechanical theory of the sediments.

Finally, it is evident from Table 4, that if we take 50 beds together and compare them with the 50 lying next beneath them, in other words, when we compare together two masses of the formation one or two hundred feet thick,—it is evident that, in one long age of deposit, more clay and magnesia were present in the ocean than in the preceding (or succeeding) long age.

We have then a large curve of variation, including many small curves, much more strongly marked than in the large one ; like the monthly curves superposed upon the annual path of the moon.

Were it not reckless to hazard a suggestion that the source of the magnesian element is to be sought for in some theory of the ejection and distribution of volcanic dust, so that each short time of volcanic disturbance has left its own record in a dolomite bed,—we might proceed one step further and find in the larger differences indicia of ages of greater or less volcanism.

Daubrée in his "Synthetical Studies and Experiments on Metamorphism, &c.," says (see Smithsonian Report for 1861, page 269) :

"We know that certain dolomites result from the transformation of limestone. This epigeny may be explained by the action of combinations of magnesia or carbonate of lime. There is, however, nothing to prove that this transformation into dolomite has always been produced by the same agents, and that the dolomite of Campo-Longo, for instance, with its tourmalines, corundums and various minerals, is to be assimilated with the dolomite of the other parts of the Alps and of Nice, or those which are near the deposits of calamine in Belgium.

But there are dolomites, and this is the case with the greatest numbers situated in regular beds, which are often horizontal, constituting very extensive geognostic formations. When they contain remains of testaceous mollusca the shell has disappeared ; they are often crystalline and riddled with holes in such a way as to suggest a substitution. It is possible that the principal part of these last dolomites was directly precipitated. But on account of the disappearance of the shells we must admit, with Elie de Beaumont, that this second case allies itself with the first, by the reaction which the medium has exerted on the matter precipitated, a reaction of such a kind that the carbonate of lime has disappeared. Indeed we notice that pure limestone never alternates with them."

This is certainly not the case in respect of the 115 beds of our section ; for certainly the limestone beds of Table 7 (A), page 121 above, with only 2 p. c. carb. mag. and 1.4 p. c. insol. matter, have a right to be classed with pure limestones.

The disappearance of shells by solution is not one of the noticeable features of the limestone strata under discussion in this paper ; and they do not, as a rule, exhibit any cavities assignable to such a cause. They are non-fossiliferous, not because of the destruction of fossils, but because of the absence of large forms of life in the original sediments.

The researches of Mr. E. T. Hardman, of the Geological Survey of Ireland, published in No. 7 of the Proceedings of the R. Irish Academy, Vol. II, Ser. II, Jan. 1877, valuable as they are, give us little assistance, because his specimens were taken from the walls of caverns in cavernous limestones, where metasomatic action was in open activity.

In the Jahrbuch der K. K. Geol. Reichsanstalt, XXV, 1875, p. 293, MM. Doelter and Hörnes discuss the subject and assign 1. to the slightly magnesian limestones a directly organic origin ; 2. to sporadic normal dolomites a later metamorphosis by percolation ; 3. to the largest part of the dolomitoid rocks an original organic origin, with subsequent change of the fossils by magnesia salts, during or shortly after deposition, and still later local lixiviation and concentration.